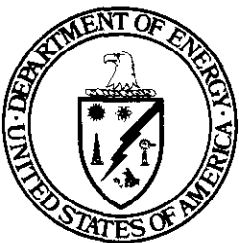


# **Comprehensive Report to Congress Clean Coal Technology Program**

## **Advanced Flue Gas Desulfurization (AFGD) Demonstration Project**

**A Project Proposed By  
Pure Air, a joint venture company**



**November 1989**

**U.S. Department of Energy  
Assistant Secretary for Fossil Energy  
Office of Clean Coal Technology  
Washington, DC 20585**

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## 1.0 EXECUTIVE SUMMARY

In December 1987, Public Law No. 100-202, as amended by Public Law No. 100-446, provided \$575 million to conduct cost-shared Innovative Clean Coal Technology (ICCT) projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities. To that end, a Program Opportunity Notice (PON) was issued by the Department of Energy (DOE) in February 1988, soliciting proposals to demonstrate technologies capable of being commercialized in the 1990s that are more cost effective than current technologies and capable of achieving significant reduction of sulfur dioxide (SO<sub>2</sub>) and/or nitrogen oxides (NO<sub>x</sub>) emissions from existing coal burning facilities, particularly those that contribute to transboundary and interstate pollution.

In response to the PON, 55 proposals were received by the DOE in May 1988. After evaluation, 16 projects were selected for funding. These projects involve both advanced pollution control technologies that can be "retrofitted" to existing facilities and "repowering" technologies that not only reduce air pollution but also increase generating plant capacity.

One of the 16 projects selected for funding is a project proposed by Pure Air for the demonstration of an Advanced Flue Gas Desulfurization (AFGD) process. This project will utilize an innovative wet limestone flue gas desulfurization (FGD) technology to achieve a high level of SO<sub>2</sub> removal (90 to 95 percent capability) on high sulfur U.S. coals at low capital and operating costs.

Several important features will be demonstrated in this project including the use of multiple boilers connected to a single, large 528 MWe, single loop, in situ oxidation absorber module that will produce high quality gypsum from a range of high sulfur coals. These features will decrease costs for both installation and operation. In addition, a Wastewater Evaporation System (WES) is included to minimize water disposal problems inherent with many high chloride content U.S. coals. The production and sales of high quality by-product gypsum will also contribute to the cost-effectiveness of this demonstration project and may eliminate the problem of solid waste disposal. Another feature of this project which will reduce the cost of achieving SO<sub>2</sub> emissions control is the purchase and direct injection of powdered limestone in lieu of limestone milling operations.

Pure Air is a joint venture company made up of Air Products and Chemicals, Inc., and Mitsubishi Heavy Industries America, Inc. (MHIA). Pure Air intends to

establish a project company known as Pure Air on the Lake which would own and operate the FGD facility and provide cost effective flue gas treatment services to the Northern Indiana Public Service Company (NI). Air Products and Chemicals, Inc. will provide the funding for the project company and will operate the AFGD plant during the demonstration phase. Following completion of work under the Cooperative Agreement, NI and Pure Air plan to enter into a long-term contract under which the project company will operate the demonstration facility as a commercial plant to provide SO<sub>2</sub> removal services for NI's Bailly Station.

This project will be carried out at NI's Bailly Generating Station which is located approximately 12 miles northeast of Gary, Indiana in Porter County (Figure 1). It will treat the total flue gas from two boilers with a combined capacity of 528 MWe and a potential capacity of 614 MWe.

The Bailly Station currently burns coal of 3.1 percent sulfur content with SO<sub>2</sub> emissions of approximately 6 lbs/mm BTU. During the demonstration period, test coals of 2.0 to 4.5 percent sulfur will be burned with 90 percent of the SO<sub>2</sub> being removed from the flue gas (down to 0.6 lbs/mm BTU). During the demonstration period of this Cooperative Agreement it is anticipated that SO<sub>2</sub> emissions from the Bailly plant will be reduced by approximately 50,000 to 60,000 tons/yr.

This demonstration project will be performed over a 68 month period. Phases I and II, design and permitting and construction and start-up, will require 35 months. Phase III, operation and disposition, will overlap Phases I and II by three months, and will require three years for completion.

The total project cost is \$150,497,000. The co-funders are DOE (\$63,434,000); Pure Air (\$68,815,000) and NI (\$18,248,000). NI will provide the use of its Bailly facility as the host site. NI will also modify the station, build a new stack, provide utilities and do site preparation and associated engineering.

## **2.0 INTRODUCTION AND BACKGROUND**

The domestic coal resources of the United States play an important role in meeting current and future energy needs. During the past 15 years, considerable effort has been directed to developing improved coal combustion, conversion, and

**Bailly Generating Station  
Northern Indiana Public Service Company  
Porter County, Indiana**



**FIGURE 1. PURE AIR AFGD DEMONSTRATION PROJECT  
SITE LOCATION.**

utilization processes to provide efficient and economic energy options. These technology developments permit the use of coal in a cost-effective and environmentally acceptable manner.

## 2.1 Requirement for Report to Congress

In December 1987, Congress made funds available for the ICCT Program in Public Law No. 100-202, "An Act Making Appropriations for the Department of Interior and Related Agencies for the Fiscal Year Ending September 30, 1988, and for Other Purposes" (the "Act"). This Act provided funds for the purpose of conducting cost-shared clean coal technology projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities and authorized DOE to conduct the ICCT Program. Public Law No. 100-202, as amended by Public Law No. 100-446, provided \$575 million, which will remain available until expended, and of which (1) \$50,000,000 was available for the fiscal year beginning October 1, 1987; (2) an additional \$190,000,000 was available for the fiscal year beginning October 1, 1988; (3) an additional \$135,000,000 will be available for the fiscal year beginning October 1, 1989; and (4) \$200,000,000 will be available for the fiscal year beginning October 1, 1990. Of this amount, \$6,782,000 will be set aside for the Small Business and Innovative Research Program, and is unavailable to the ICCT Program.

In addition, after the projects to be funded had been selected, DOE prepared a comprehensive report on the proposals received. The report was submitted in October 1988 and was entitled "Comprehensive Report to Congress: Proposals Received in Response to the Innovative Clean Coal Technology Program Opportunity Notice" (DOE/FE-0114). Specifically, the report outlines the solicitation process implemented by DOE for receiving proposals for ICCT projects, summarizes the project proposals that were received, provides information on the technologies that are the focus of the ICCT Program, and reviews specific issues and topics related to the solicitation.

Public Law No. 100-202 directed DOE to prepare a full and comprehensive report to Congress on each project selected for award under the ICCT Program. This report is in fulfillment of this directive and contains a comprehensive description of the Advanced Flue Gas Desulfurization Demonstration Project.

## 2.2 Evaluation and Selection Process

A PON was issued by DOE on February 22, 1988, to solicit proposals for conducting cost-shared ICCT demonstrations. Fifty-five proposals were received. All proposals were required to meet the six qualification criteria provided in the PON. Failure to satisfy one or more of these criteria resulted in rejection of the proposal. Proposals that passed Qualification Review proceeded to Preliminary Evaluation. Three preliminary evaluation requirements were identified in the PON. Proposals were evaluated to determine whether they met these requirements; those proposals that did not were rejected.

Of those proposals remaining in the competition, each offeror's Technical Proposal, Business and Management Proposal, and Cost Proposal were evaluated. The PON provided that the Technical Proposal was of somewhat greater importance than the Business and Management Proposal and that the Cost Proposal was of minimal importance; however, everything else being equal, the Cost Proposal was very important.

The Technical Evaluation Criteria were divided into two major categories. The first, "Commercialization Factors", addressed the projected commercialization of the proposed technology. This was different from the proposed demonstration project itself and dealt with factors involved in the commercialization process. The criteria in this section provided for consideration of (1) the potential of the technology to reduce total national emissions of SO<sub>2</sub> and/or NO<sub>x</sub> emissions and reduce transboundary and interstate air pollution with minimal adverse environmental, health, safety, and socio-economic (EHSS) impacts; and (2) the potential of the proposed technology to improve the cost-effectiveness of controlling emissions of SO<sub>2</sub> and NO<sub>x</sub> when compared to commercially available technology options.

The second major category, "Demonstration Project Factors," recognized the fact that the proposed demonstration project represents the critical step between "predemonstration" scale of operation and commercial readiness, and dealt with the proposed project itself. Criteria in this category provided for the consideration of the following: the technical readiness for scale-up; the adequacy and appropriateness of the demonstration project; the EHSS and other site-related aspects; the reasonableness and adequacy of the technical approach; and the quality and completeness of the Statement of Work.

The Business and Management Proposal was evaluated to determine the business and management performance potential of the offeror, and was used as an aid in determining the offeror's understanding of the technical requirements of the PON. The Cost Proposal was reviewed and evaluated to assess the validity of the proposer's approach to completing the project in accordance with the proposed Statement of Work and the requirements of the PON.

Consideration was also given to the following program policy factors:

- (1) The desirability of selecting projects for retrofitting and/or repowering existing coal-fired facilities that collectively represent a diversity of methods, technical approaches, and applications (including both industrial and utility).
- (2) The desirability of selecting projects that collectively produce some near-term reduction of transboundary transport of emitted  $\text{SO}_2$  and  $\text{NO}_x$ .
- (3) The desirability of selecting projects that collectively represent an economic approach applicable to a combination of existing facilities that significantly contribute to transboundary and interstate transport of  $\text{SO}_2$  and  $\text{NO}_x$  in terms of facility types and sizes, and coal types.

The PON also provided that, in the selection process, DOE would consider giving preference to projects located in states where the rate-making bodies of those states treat innovative clean coal technologies the same as pollution control projects or technologies. The inclusion of this project selection consideration was intended to encourage states to utilize their authorities to promote the adoption of innovative clean coal technology projects as a means of improving the management of air quality within their areas and across broader geographical areas.

The PON provided that this consideration would be used as a tie breaker if, after application of the evaluation criteria and the program policy factors, two projects received identical evaluation scores and remained essentially equal in value. This consideration would not be applied if, in doing so, the regional geographic distribution of the projects selected would be altered significantly.



An overall strategy for compliance with the National Environmental Policy Act (NEPA) was developed for the ICCT Program, consistent with the Council on Environmental Quality regulations for implementing NEPA and the DOE guidelines for compliance with NEPA. This strategy includes both programmatic and project-specific environmental impact considerations during and after the selection process.

In light of the tight schedule imposed by Public Law No. 100-202 and the confidentiality requirements of the competitive PON process, DOE established alternative procedures to ensure that environmental factors were fully evaluated and integrated into the decision-making process to satisfy its NEPA responsibilities. Offerors were required to submit both programmatic and project-specific environmental data and analyses as a discrete part of each proposal submitted to DOE.

The DOE strategy for NEPA compliance has three major elements. The first involves preparation of a programmatic environmental impact analysis for public distribution, based on information provided by the offerors and supplemented by DOE, as necessary. This environmental analysis documents that relevant environmental consequences of the ICCT Program and reasonable programmatic alternatives are considered in the selection process. The second element involves preparation of a preselection project-specific environmental review for internal DOE use. The third element provides for preparation by DOE of publicly available site-specific NEPA documents for each project selected for financial assistance under the ICCT Program.

No funds from the ICCT Program will be provided for detailed design, construction, operation, and/or dismantlement until the third element of the NEPA process has been successfully completed. In addition, each Cooperative Agreement entered into will require an Environmental Monitoring Plan (EMP) to ensure that significant technology, project, and site-specific environmental data are collected and disseminated.

After considering the evaluation criteria, the program policy factors, and the NEPA strategy, sixteen proposals were selected for negotiation and award. The Advanced Flue Gas Desulfurization proposal submitted by Pure Air was one of these proposals.

### 3.0 TECHNICAL FEATURES

#### 3.1 Project Description

The Pure Air project will demonstrate that, by combining Advanced Flue Gas Desulfurization (AFGD) technology, highly efficient plant operation and maintenance capabilities and by-product gypsum sales, significant reductions of SO<sub>2</sub> emissions can be achieved at approximately one-half the life cycle cost of conventional FGD systems. Further, this emission reduction will be achieved without generating solid waste and while minimizing liquid waste disposal by-products.

This project will utilize MHIA's basic wet limestone FGD technology, while incorporating many advanced features to achieve high SO<sub>2</sub> removal efficiency (90 to 95%) on high-sulfur U.S. coals. The use of a single, 528 MWe module is one of these features. Conventional wet FGD systems are typically limited to single modules of about 125 MWe and use multiple, parallel modules for larger power plants. Spare modules are usually included for backup purposes. The use of multiple modules tends to increase both capital and operating cost when conventional FGD is applied to large boilers or to power plants consisting of multiple smaller boilers.

A second important feature concerns Pure Air's approach to reducing costs via gypsum production. In a wet limestone scrubber, SO<sub>2</sub> is reacted with limestone (or calcium carbonate, CaCO<sub>3</sub>) to produce calcium sulfite (CaSO<sub>3</sub>) which may then be oxidized to form usable gypsum (or calcium sulfate, CaSO<sub>4</sub>). In conventional wet FGD installations, these process steps are carried out in separate vessels. In the Pure Air process, SO<sub>2</sub> absorption and oxidation of CaSO<sub>3</sub> to CaSO<sub>4</sub> occur in a single vessel. This is an important project feature that is referred to as single loop, in situ oxidation. The elimination of a separate oxidation vessel and its associated equipment will significantly reduce costs for installations where gypsum is a commercial by-product.

Also, a high velocity co-current absorber will be demonstrated. This design feature will conserve costs and space, making the AFGD system especially useful for retrofit applications.

The use of a wastewater evaporation system (WES) to greatly reduce or eliminate the water disposal problems ordinarily associated with conventional FGD and high-chlorine U.S. coals is another important technical feature of this demonstration.

Finally, this project will explore the use of a novel business concept, i.e., that a company other than the utility will own and operate the AFGD plant. This allows the electric utility company to avoid large capital outlays for SO<sub>2</sub> removal and to avoid the operating problems that are normally associated with running a chemical plant.

The goal of this project is to demonstrate the technical and economic feasibility of the AFGD technology in a full scale, commercially operating utility power station which burns high sulfur U.S. coal. If successful, the process will achieve 90% SO<sub>2</sub> removal at capital and operating costs which are approximately one-half of those realized for conventional wet limestone FGD facilities.

### 3.1.1 Project Summary

Project Title:	Advanced Flue Gas Desulfurization (AFGD) Demonstration Project
Proposer:	Pure Air, a Joint Venture Company
Project Location:	Northern Indiana Public Service Company Bailly Station, Porter County, Indiana
Technology:	Flue Gas Desulfurization
Application:	New and Retrofit Utility and Industrial Coal- and Oil-Fired Boilers
Types of Coal Used:	High Sulfur Bituminous Coal (Illinois/Indiana Basin) at 2.0% to 4.5% Sulfur
Product:	Emissions Control
Project Size:	528 MWe (1,420,000 scfm Capacity)
Project Start Date:	October 1989
Project End Date:	June 1995

### 3.1.2 Project Sponsorship and Cost

Project Sponsor:	Pure Air	
Co-Funders:	Pure Air U.S. Department of Energy Northern Indiana Public Service Company	
Estimated Project Cost:	\$150,497,000	
Cost Distribution:	Participant <u>Share(%)</u>	DOE <u>Share(%)</u>
	57.8	42.2

## 3.2 Advanced Flue Gas Desulfurization (AFGD) Demonstration Project

### 3.2.1 Overview of Process Development

The process demonstrated by this project contains several innovative features which have been either tested at the pilot plant scale or commercially applied to some extent in oil-fired and low sulfur coal-fired plants. The AFGD process is similar to conventional wet FGD plants with forced oxidation where the use of pulverized limestone slurry to absorb  $\text{SO}_2$  is the standard technology. However, this demonstration project will incorporate a number of changes to conventional systems. Each of these major changes will be discussed below.

The absorber module for the Bailly station will be sized to clean the entire flue gas stream from two units with a total capacity of 528 MWe. As noted previously, typical U.S. applications use multiple absorbers sized at approximately 125 MWe and include one spare module to increase reliability. Larger single units have been successfully used elsewhere. In Japan, single units of up to 700 MWe have been installed using a limestone reagent and producing commercial gypsum.

The use of a single absorber module with no spare is common practice outside the U.S. While the use of larger, more reliable, and more cost efficient modules is technically feasible, the use of spare modules is the standard practice in the

U.S. due to the New Source Performance Standards (NSPS) of the Clean Air Act which requires that the FGD system must operate whenever the boiler operates. Since the Bailly station is a retrofit installation, NSPS do not apply.

Typical wet FGD systems use countercurrent flow in which the flue gas enters the base of the scrubber and passes upward through sprays of the scrubbing slurry which falls through the rising gas. Pure Air's AFGD system uses high velocity co-current flow. The use of co-current flow, in which both the gas and scrubbing slurry are introduced at the top of the scrubber and pass downward through the scrubber, has been used in the U.S. at the 10 MWe scale (TVA's Shawnee Plant) and the 125 MWe scale (Hoosier Energy's Merom Station). Worldwide, co-current scrubbers treat the flue gas from power plants with a combined capacity of 12,000 MWe. These plants' gas velocities, however, are significantly less than the 20 feet per second proposed for this project, which is based on pilot plant work in Japan.

Conventional wet FGD systems often treat the flue gas in a prequencher to remove chlorides and particulate matter before they enter the absorber. This prequencher/absorber arrangement is termed a "dual loop system." In many conventional wet FGD systems which produce commercial grade gypsum as a byproduct,  $\text{SO}_2$  removal occurs in the absorber, while the oxidation of  $\text{CaSO}_3$  to  $\text{CaSO}_4$  is performed in another, completely separate, reaction vessel. This set-up is referred to as "ex situ oxidation." Thus, the combination of a dual loop scrubbing system with ex situ oxidation for commercial gypsum production generally utilizes three reaction vessels. A dual loop system with ex situ oxidation represents the worldwide standard for producing a commercial quality gypsum byproduct whenever high levels of flyash and halogen contaminants are entrained in the flue gas. Pure Air's AFGD process utilizes a single loop system with in situ oxidation. This arrangement eliminates the prequencher and further combines the absorption and oxidation operations into a single vessel.

In conventional wet FGD systems in which the oxidation step is carried out in a separate vessel, fixed sparger arrangements are used. These are basically a large array of submerged, perforated pipes that distribute the oxidation air. Separate mixing is provided by mechanical mixers or pumps which recirculate the slurry. The air rotary sparger to be demonstrated at the Bailly site is specially designed to combine the functions of oxidation air distribution and stirring in the absorber. This design has been tested at the 50 MWe level in Japan. The hollow shaft for this sparger has been constructed at the size needed for a 125 MWe module and will be scaled up for this application. In this

demonstration, the air rotary sparger will be supplemented by some fixed sparging to ensure complete oxidation.

In conventional systems, the wastewater that cannot be recycled to the process must be sent to a disposal pond or treatment plant prior to discharge. This treatment increases operating expenses and can be costly. In the AFGD process, waste heat in the flue gas is used to evaporate the wastewater. The wastewater evaporation system (WES) proposed for this project has been demonstrated on a 125 MWe oil-fired boiler in Japan. At the Bailly station, the WES will be tested on the 345 MWe boiler, but not on the 183 MWe boiler. If the WES were sized to treat all 528 MWe of generating capacity, zero liquid discharge would be possible.

Conventional FGD plants include equipment to pulverize limestone. Directly injecting purchased pulverized limestone into the process will reduce capital costs and power consumption. This feature has been applied at only one other power plant -- a 370 MWe West German facility which burns brown coal.

In summary, this is not a process which developed from laboratory scale to pilot scale to commercial scale. Rather, it is a process which combines a number of improvements to the basic wet FGD process which have been separately demonstrated at various sizes.

### 3.2.2 Process Description

The AFGD system, shown schematically in Figure 2 is divided into four sections:

- o Flue Gas Ducting and Fans Section
- o Limestone Feed Section
- o SO<sub>2</sub> Removal Unit Section
- o Gypsum By-Product Handling Section

Figure 2 is a simplified process flow diagram which shows the single loop absorber module and its relationship to the other sections of the process. These sections will be described separately.

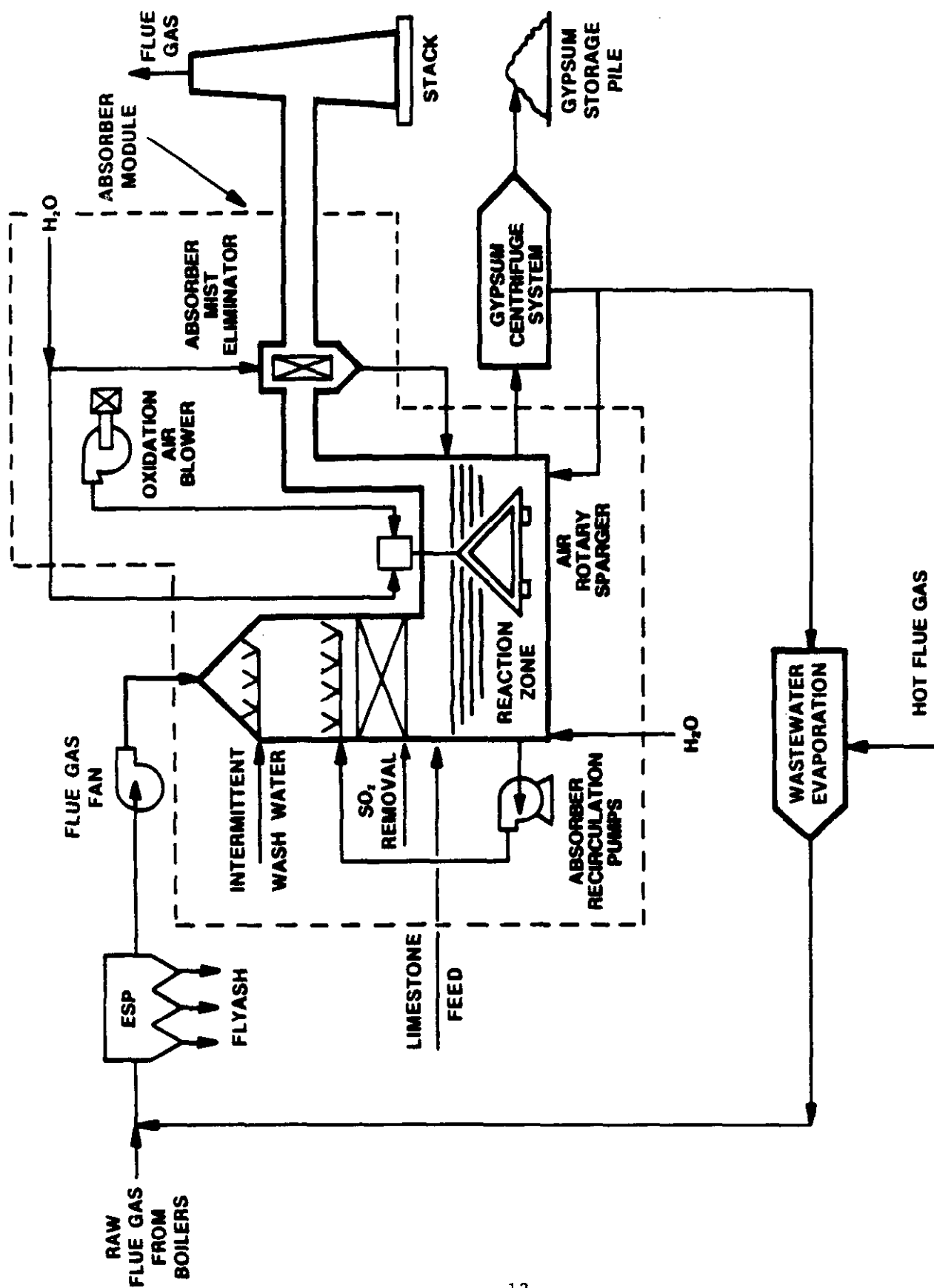


FIGURE 2. PURE AIR ADVANCED FLUE GAS DESULFURIZATION PROCESS.

### Flue Gas Ducting and Fans Section

The flue gas ducting and fans section directs flue gas from the existing Bailly Generating Station electrostatic precipitators (ESP) to the AFGD system SO<sub>2</sub> removal section. A section of the ductwork, upstream of the ESP, receives wastewater from the WES.

### Limestone Feed Section

The AFGD system will receive pulverized limestone purchased from a limestone supplier. The limestone will have been pulverized to 95 percent less than 325 mesh (44 microns) by the supplier. Limestone will be pneumatically unloaded into limestone storage silos. The total limestone storage capacity will be three days at maximum boiler load. The pulverized limestone will be fed from the storage silos into a pneumatic conveying system, that will feed the limestone directly into the absorber hold tank. The limestone feed rate corresponds to a nominal 1.05 Ca/S molar ratio (based on the SO<sub>2</sub> removed) to achieve 90 percent or higher SO<sub>2</sub> removal. This Ca/S molar ratio also helps maintain the by-product gypsum purity.

Hydrated lime will be received by truck, pneumatically conveyed to a small silo, and added directly to the wastewater tank by a pump. The hydrated lime is added to the wastewater to raise the pH of the wastewater during operation of the WES.

### SO<sub>2</sub> Removal Unit Section

The flue gas from the flue gas ducting and fans section will enter the AFGD absorber at its top where it will be quenched with a recirculating limestone slurry. This "wet/dry" interface will be washed intermittently with fresh water to avoid the formation of any deposits.

The single loop absorber module at the Bailly station will be a co-current grid packed tower. The absorber tower and reaction tank will be integrated to reduce equipment and space requirements. The co-current design will allow a gas velocity as high as 20 feet per second. This accounts for the inherently compact size of the absorber. Typical spray towers using countercurrent operation achieve gas velocities in the range of only 10 feet per second.

The grid packing will provide a large surface area for liquid/gas contact which enhances overall SO<sub>2</sub> removal efficiency. The absorbed SO<sub>2</sub> will be partially



oxidized by the oxygen in the flue gas as it passes through the absorption grids. Complete oxidation, which converts calcium sulfite to calcium sulfate (gypsum), will be accomplished in a reaction tank by using a newly designed air rotary sparger.

The absorber reaction tank will be designed to hold an adequate liquid volume to ensure efficient utilization of the limestone, precipitation of calcium sulfate, and oxidation of the remaining calcium sulfite. The air rotary sparger system is an innovative mixer that injects air into the reaction tank and prevents solids from settling out in the reaction tank. The gypsum slurry will be drawn off to maintain a 20 to 25 percent (by weight) slurry content in the absorber reaction tank. Two absorber bleed pumps will transfer the slurry from the absorber to the centrifuge feed tank for further processing. Each pump is sized to handle 100 percent of the required flow rate.

After flowing downward through the absorption grids, the flue gas will turn, pass over the reaction tank, and turn upward towards the mist eliminator located in the outlet ducting. The recirculation slurry is separated from the gas by the mist eliminator. A two-stage mist eliminator will be installed in a horizontal run between the absorber tank and the stack. Collected entrainment will be returned to the absorber tank. A washing spray header system will be installed in front of the mist eliminator elements to intermittently wash down the element surface and avoid any build-up of deposits. After passing through the mist eliminators, the scrubbed flue gas will exit the outlet duct into the exhaust stack for discharge to the atmosphere.

#### Gypsum By-Product Handling

In the gypsum by-product handling section, two absorber bleed pumps will batch transfer the gypsum slurry from the SO<sub>2</sub> removal unit section into basket centrifuges. The centrifuges will reduce the slurry to a dewatered gypsum cake containing 8 to 10 percent moisture by weight. A portion of the filtrate water from the centrifuge operation will be returned to the absorber vessel as process water. The wastewater from the centrifuge operation will be disposed of within the guidelines of the existing permit for the Bailly Station. The gypsum cake will be transferred by enclosed conveyor to a temporary storage building within the station where it can be taken to a wallboard manufacturer or hauled off-site for landfilling. All on-site gypsum operations will be fully enclosed, in order to minimize fugitive dust emissions.

During the three-year demonstration phase, a portion of the filtrate water from the centrifuge operation will be sent to the WES for disposal treatment. In the WES, wastewater from the absorber system will be fed into a pH adjustment tank. In the tank, wastewater will be neutralized by hydrated lime. Impurities in the wastewater such as chloride and sulfate ions will be stabilized by the neutralization so that these impurities do not evaporate. After pH adjustment, wastewater will be pressurized by the wastewater spray pump and pumped to the wastewater evaporators located upstream of the ESP in the flue gas ducting and fans section.

Wastewater will then be atomized by a pressure nozzle in the duct, mixed with the flue gas, and evaporated to dryness through the evaporator. After evaporation, the flue gas with dry solids will be ducted to join the main flue gas stream at the evaporator outlet and the dry solids will be removed by the ESP. During demonstration periods when the WES is not in operation, the wastewater will be disposed of within the guidelines of the existing discharge permit for the Bailly Station.

### 3.2.3 Application of Processes in Proposed Project

This project is intended to demonstrate the technical, environmental and economical viability of the AFGD process. This project will result in the installation and integration of a full scale AFGD system into a fully commercial electric generating station. It will clean the entire flue gas stream from two boilers with a combined capacity of 528 MWe, or greater. It will be installed at NI's Bailly Station located in Porter County, Indiana. It will be a full size commercial installation and will include all the equipment and subsystems that will be part of future commercial installations.

This project will demonstrate the ability of the process to remove at least 90 percent of the SO<sub>2</sub> from the flue gas. In addition, it will demonstrate the reliability of the system which uses a single absorber module to the U.S. utility industry. It will also demonstrate the ability of the AFGD system to produce a marketable gypsum by-product. Therefore, this project will demonstrate all applicable performance, equipment and cost factors for the AFGD technology.

### 3.3 General Features of the Project

#### 3.3.1 Evaluation of Developmental Risk

The AFGD process contains several developmental features. To various degrees these features have been pilot plant tested or commercially applied in similar applications such as oil-fired plants or low-sulfur coal applications. However, these features have not been previously combined in a single system and have not generally been applied either in this country or on a medium-to-high sulfur coal. As with any new or emerging technology, there is an element of risk involved with its continued development and scale-up. However, most elements of the AFGD process have already been demonstrated on a commercial scale. This process is made up of proven features, the result of development programs that started with initial bench scale research and proceeded through pilot plant work and small-scale demonstrations.

This project will provide:

- o The final technical demonstration needed for the process;
- o Needed data on the process effects upon the environment and plant equipment; and
- o Applicable economic, technical, and environmental experience necessary to support commercialization decisions.

Technical risks associated with this project include potential problems with solids build-up and corrosion in the absorber module and mist eliminator, integration of the various innovative features into a single process, and overall system performance. Serious problems in such technical areas also constitute an economic risk. All of these risks can be readily addressed through normal engineering practices associated with the design, construction, and operation of a large integrated plant. The successful operation of the individual features at the commercial-scale indicates that they can be successfully operated in an integrated fashion. Further, all components are typical of those in use today, so no unusual design or fabrication techniques will be required. Considering the nature of the risks and the means available to mitigate them, a low to moderate risk has been assigned to this project.

#### 3.3.1.1 Similarity of the Project to Other Demonstration/ Commercial Efforts

Commercially available FGD processes for use with high-sulfur coals include, among others, conventional wet limestone, forced oxidation limestone, dual alkali, and wet lime. These systems are generally comparable in sulfur removal performance; the major differences are in such areas as costs, sludge characteristics, system reliability, and chemical utilization. The Pure Air project will demonstrate an innovative process which consists of numerous improvements to the commonly used wet limestone FGD technology. It therefore bears some similarity to many wet limestone scrubbing installations.

Innovative features of the Pure Air project include the high velocity co-current absorber, the wastewater evaporation system, and the use of a single absorber module for multiple boilers. This combination of features conserves costs and space. It also leads to minimal, and potentially zero, waste disposal requirements. Thus, the AFGD technology is especially attractive for retrofit applications, with life cycle costs projected to be only 50-60 percent of the costs for conventional wet limestone scrubber technology.

Additionally, Pure Air's novel own-and-operate concept provides a low risk business alternative for electric utility companies that would like the option of contracting-out for environmental control services, so that they may focus on their primary business of electric power generation.

Another ICCT project which uses a single absorber vessel with no spare is the demonstration of the Chiyoda Thoroughbred-121 (CT-121) process proposed by Southern Company Services, Inc. That process also produces gypsum by carrying out the oxidation step in the same vessel as the absorption step. However, the CT-121 process uses a vessel in which the flue gas is bubbled through the limestone slurry as opposed to the co-current spray tower used by the AFGD process.

#### 3.3.1.2 Technical Feasibility

The AFGD process will utilize MHIA's basic wet limestone FGD technology while incorporating many advanced features to achieve high SO<sub>2</sub> removal efficiency (90-95%) on high-sulfur U.S. coals at low capital and operating costs for both new and retrofit applications.

Serious work on the conventional limestone FGD technology started approximately 20 years ago. Early work involved pilot scale tests using various sorbents to evaluate  $\text{SO}_x$  absorption under various operating conditions. The effects of sorbents and additives on ash deposition and ash properties were also studied. This work was followed by commercial scale tests using limestone, with general acceptance of the FGD limestone technology by U.S. power utilities and process firms using high or medium sulfur content coal as fuel for their plants.

The degree of technical feasibility of the innovative features to be used in this project appears to be well documented and is suitable for the purpose of this project. The favorable experience for these features to be obtained on this project should permit full commercialization of the Pure Air AFGD process following a successful demonstration.

#### 3.3.1.3 Resource Availability

Pure Air and NI have already entered into a Flue Gas Processing Agreement. Under this agreement, Pure Air will raise the capital required to construct the AFGD Project and NI will raise the capital required for modifications to the power station. Approximately 75-80 percent of the private funding for the AFGD facility will be raised through debt. The rest will be funded by equity. NI will contribute to the Participant's cost share by financing several site modifications which are required in order to smoothly integrate the AFGD facility into the Bailly station. DOE will share approximately 42% of the project's cost.

Pure Air will furnish the manpower to operate and maintain the AFGD project and NI will furnish the personnel to operate and maintain the conventional portion of the Bailly plant. NI owns both the land and the power generating facility. Pure Air will be responsible for engineering, design, construction, financial, and other administrative and management functions required to execute this project. The resources, technical expertise, and top management of NI are fully supportive of this project. NI staffs and maintains its own support activities, including laboratories, computer facilities, accounting, legal, engineering, project management, design, environmental, and construction departments. Adequate local manpower exists to construct and operate the facility.

Additional water and electrical power will be required. Since the plant is located adjacent to Lake Michigan, the water supply is more than adequate. Electrical power will be available from the Bailly Station.

High-sulfur coal and limestone are both available from nearby suppliers and the plant is served by major highways and a railroad. Discussions have been undertaken with a second railroad about the possibility of adding a spur to serve Bailly Station. Therefore, the necessary materials are readily available for this project.

### 3.3.2 Relationship Between Project Size and Projected Scale of Commercial Facility

NI's host facility, the Bailly Electric Generating Station, consists of two coal-fired units, and a small gas-fired auxiliary unit. The first and older unit is rated at 183 MWe, while the second is rated at 345 MWe. Each unit has its own steam generator connected to its electrical generator. Total electric capability is 528 MWe, but could be increased to 614 MWe should certain changes in the boiler design be undertaken. The absorber module to be used for this CCT project will be rated for the entire possible plant capacity of 614 MWe, and will be the largest single scrubber module ever built and operated in the U.S. Consequently, the absorber to be used in this project is of a full-scale commercial size for the U.S. market.

### 3.3.3 Role of the Project in Achieving Commercial Feasibility of the Technology

The proposed demonstration will provide the needed long-term performance data typical of large utility boiler operation. This will provide the users, the utilities, the regulatory agencies and others with a clearer understanding of the benefits of the technology. The economics and commercial feasibility of this process will be established in a full size plant under actual working conditions.

#### 3.3.3.1 Applicability of the Data to be Generated

During the demonstration, project data will be collected to thoroughly document the technical and economic performance of the AFGD process. These data will include SO<sub>2</sub> concentrations before and after the flue gas passes through the absorber to fully evaluate the desulfurization capability. To arrive at operating and maintenance costs, data will be collected on coal use/analysis, limestone consumption, and water and power use as well as manpower needs and material costs. In addition, operating parameters such as flue gas flow rates and temperatures will be monitored and recorded to allow complete evaluation of various parameters' effects on process operation. In short, the data collected

in the course of this project will permit comprehensive evaluation of all technical and economic factors which are relevant to the commercialization of Pure Air's AFGD process.

#### 3.3.3.2 Identification of Features that Increase Potential for Commercialization

Pure Air's AFGD process incorporates a substantial number of innovative features which will increase the potential for commercialization. These are:

- o 528 MWe or larger Absorber Module - A single large module represents substantial cost savings over a multi-module design.
- o High Velocity Co-Current Absorber - The design velocity of 20 feet per second for the co-current scrubber results in an absorber size which is approximately one-half that of currently available FGD absorbers handling the same amount of flue gas.
- o Single Loop Absorber Vessel - Being able to accomplish all process steps in a single vessel represents a significant savings over commercially available dual loop systems.
- o Air Rotary Sparger - This new device will increase process efficiency by providing for better mixing of air and limestone slurry within the base of the absorber.
- o Direct Injection of Pulverized Limestone - Purchase and injection of pulverized limestone eliminates the need for on-site crushing and wet grinding facilities.
- o No Spare Module - The ability to maintain high availability without a spare module will reduce the number of equipment items. Therefore, capital, operation, and maintenance costs will also decrease.
- o Commercial Grade Gypsum - The AFGD process will produce a saleable gypsum by-product, rather than a sludge or solid waste that would require landfill disposal.

- o Wastewater Evaporation System - Wastewater disposal often poses a difficult problem for scrubber operators. This novel feature will transform the wastewater contaminants into a solid form, which can be more easily managed using conventional particulate control equipment.
- o Project Company Ownership - Ownership by Pure Air will allow the utility to have the benefits of flue gas desulfurization without tying up utility company capital and without having to operate what is essentially a chemical plant, as opposed to a power plant.

Once commercially proven, the Pure Air process should provide an economic and technically acceptable means of controlling SO<sub>2</sub> from coal-fired boilers. Of particular significance is the fact that certain design features of the AFGD process serve to minimize space and land use requirements. This, coupled with other cost saving features, makes the AFGD technology especially well suited for retrofit applications. In addition, Pure Air estimates the installation costs, even for new plants, to be approximately one-half the cost of conventional wet limestone scrubber technology.

#### 3.3.3.3 Comparative Merits of Project and Projection of Future Commercial Economics and Market Acceptability

The proposed demonstration is a complete commercial scale evaluation of the Pure Air AFGD process technology for SO<sub>2</sub> control.

Other flue gas desulfurization processes available in the U.S. have achieved market acceptability and have demonstrated their commercial economics by successfully operating for periods extending over several years. Pure Air expects to demonstrate 90% SO<sub>2</sub> removal and favorable economics for its AFGD process through a three year operating period to gain market acceptability.

Particular advantages for this project are that it is being carried out at a 528 MWe power plant, which is representative of many U.S. power plants and that a complete, fully integrated process will be installed and operated for a three year demonstration. After the demonstration, plans call for the same plant to continue operation for 17 years as a fully commercial desulfurization facility. During this period Pure Air on the Lake will continue to own and operate the AFGD



plant and will provide SO<sub>2</sub> removal services to the utility plant under a long-term contract.

Future marketability, following a successful demonstration, will be enhanced by economics which compare favorably to conventional wet FGD systems. Successful demonstration of high reliability, effectiveness, and low costs can be expected to lead to acceptance by the utility industry.

#### **4.0 ENVIRONMENTAL CONSIDERATIONS**

The overall strategy for compliance with NEPA, cited in Section 2.2, contains three major elements. The first element, the Programmatic Environmental Impact Analysis (PEIA), was issued as a public document in September 1988. In the PEIA, the Regional Emission Database and Evaluation System (REDES), a model developed by DOE at Argonne National Laboratory, was used to estimate the environmental impacts that could occur by the year 2010 if each technology were to reach full commercialization and capture 100 percent of its applicable market. The environmental impacts were compared to the no-action alternative, for which it was assumed that use of conventional coal technologies continues through 2010, with new plants using conventional flue gas desulfurization controls to meet NSPS.

In the PEIA, the expected performance characteristics and applicable market of the AFGD technology were used to estimate the environmental impacts that could result if the AFGD technology were to reach full commercialization in 2010. The REDES computer model was used to project the impacts of the AFGD technology as compared to the no-action alternative.

Projected environmental impacts from maximum commercialization of the AFGD technology into national and regional areas in 2010 are given in Table 1. Negative percentages indicate decreases in emissions or wastes in 2010. Conversely, positive values indicate increases in emissions or wastes. The information presented in Table 1 represents an estimate of the environmental impacts of the technology in 2010. These computer-derived results should be regarded as approximations of actual impacts.

**Table 1. Projected Environmental Impacts in 2010  
(Percent Change in Emissions and Solid Wastes)**

Region	Sulfur Dioxide (SO <sub>2</sub> )	Nitrogen Oxides (NO <sub>x</sub> )	Solid Waste
National	-45	0	+6
Northeast	-65	0	+8
Southeast	-54	0	+8
Northwest	-10	0	+4
Southwest	-15	0	+1

Source: Programmatic Environmental Impact Analysis (DOE/PEIA-0002),  
U.S. DOE, September 1988

As shown in Table 1, significant reductions of SO<sub>2</sub> are projected to be achievable nationally due to the capability of the AFGD process to remove 90% to 95% of SO<sub>2</sub> emissions from coal-fired boilers and the wide potential applicability of the process. The AFGD process offers the potential to reduce or eliminate the problem of solid waste disposal. However, that potential is dependent upon local market conditions relating to the sale of the gypsum by-product. Accordingly, the REDES model assumed a worst-case scenario in which all of the gypsum would have to be treated as a solid waste. While this represents an increased solid waste level, the material is readily disposable. The REDES model predicts greatest environmental impacts will be felt in the Northeast because of the large amount of coal-fired capacity there that can be retrofitted with the AFGD process. The least impact occurs in the Northwest because of the minimal use of coal there. The national quadrants used in this study are shown in Figure 3.

The second element of DOE's NEPA strategy for the ICCT program involved preparation of a preselection environmental review based on project-specific environmental data and analyses that offerors supplied as a part of each proposal. This analysis, developed for internal DOE use only, contained a discussion of site-specific EHSS issues associated with each demonstration project. It included a discussion of the advantages and disadvantages of the proposed and alternative processes reasonably available to each offeror. A discussion of the impacts of each proposed demonstration on the local environment, and a list of permits that must be obtained to implement the

proposal, were included. It also contained options for controlling discharges and for management of solid and liquid wastes. Finally, the risks and impacts of each proposed project were assessed. Based on this analysis, no environmental, health, or safety issues have been identified that would result in any significant adverse environmental impacts from construction and operation of the AFGD demonstration facility.

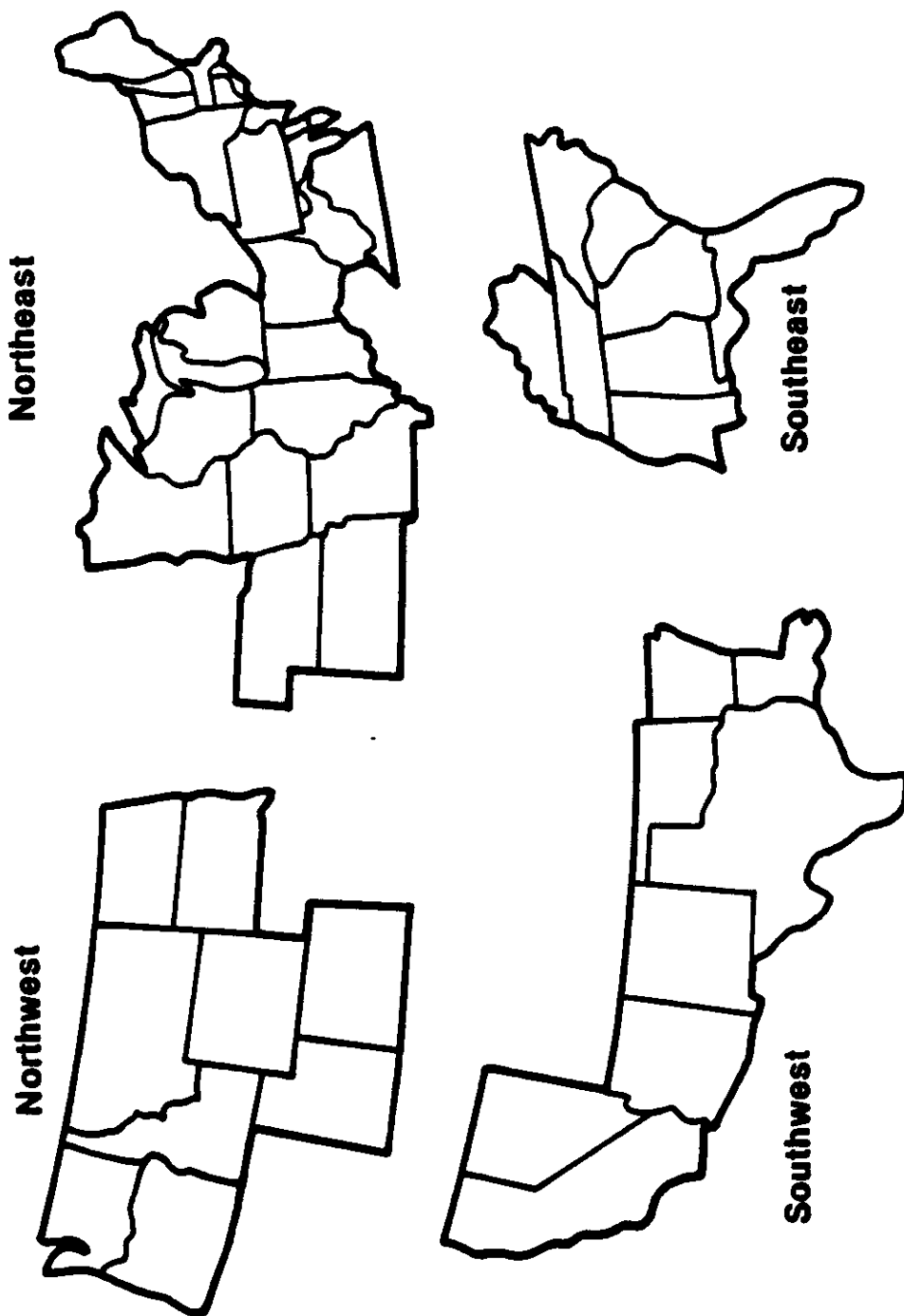
As the third element of the NEPA strategy, the Participant (Pure Air) will be required to submit the environmental information specified in Appendix J of the PON. This detailed site- and project-specific information will be used as the basis for the development of the site-specific NEPA documents to be prepared by DOE. These documents will be completed and approved in full conformance with the Council on Environmental Quality (CEQ) regulations for implementing NEPA (40 CFR Parts 1500-1508) and DOE guidelines for NEPA compliance (52 FR 47662, December 15, 1987) before federal funds are provided for detailed design, construction, and operation.

In addition to the NEPA requirements, the Participant must prepare and submit an Environmental Monitoring Plan (EMP). Guidelines for the development of the EMP are provided in Appendix N of the PON. The EMP is intended to ensure that significant technology-, project-, and site-specific environmental data are collected and disseminated to provide health, safety, and environmental information should the technology be used in commercial applications.

## **5.0 PROJECT MANAGEMENT**

### **5.1 Overview of Management Organization**

After the Cooperative Agreement is signed, Pure Air will request that DOE assign the Cooperative Agreement to Pure Air on the Lake, a limited partnership that would initially be wholly owned by Air Products and Chemicals, Inc. Assuming that assignment takes place, Pure Air on the Lake will become the Project Company, will own the AFGD plant, and will be responsible for execution of the Cooperative Agreement. Pure Air, through a turnkey contract with Pure Air on the Lake, will be responsible for the AFGD plant construction. The utilization of a Project Company is advantageous for commercializing the own-and-operate concept. Pure Air will use this arrangement to individually finance each scrubber facility that it eventually builds.



**FIGURE 3. QUADRANTS FOR THE CONTIGUOUS UNITED STATES.**

The project will be managed by the Project Manager for Pure Air on the Lake who will be the principal contact with DOE for matters regarding the administration of the Cooperative Agreement between the Project Company and DOE. All other participating organizations will report to the Project Manager. The Project Manager will report to the President of Pure Air on the Lake, who will also be the Project Company's ICCT Program Manager.

In addition to DOE, the project will be funded by Pure Air and NI. Other organizations involved in the project include the Electric Power Research Institute (EPRI) and the Stearns-Roger Division of United Engineers and Constructors. A gypsum wallboard manufacturer, a limestone supplier and a coal supplier will be selected later.

## 5.2 Identification of Respective Roles and Responsibilities

### DOE

The DOE shall be responsible for monitoring all aspects of the project and for granting or denying all approvals required by this Cooperative Agreement. The DOE Contracting Officer is the authorized representative of the DOE for all matters related to the Cooperative Agreement.

The DOE Contracting Officer will appoint a Contracting Officer's Technical Representative (COTR) who is the authorized representative for all technical matters and who will have the authority to issue "Technical Advice" which may:

- o Suggest redirection of the Cooperative Agreement effort, recommend a shifting of work emphasis between work areas or tasks, and suggest pursuit of certain lines of inquiry, which assist in accomplishing the Statement of Work.
- o Approve those reports, plans, and technical information required to be delivered by the Participant to the DOE under the Cooperative Agreement.

The DOE COTR does not have the authority to issue any technical advice which:

- o Constitutes an assignment of additional work outside the Statement of Work.

- o In any manner causes an increase or decrease in the total estimated cost or in the time required for performance of the Cooperative Agreement.
- o Changes any of the terms, conditions, or specifications of the Cooperative Agreement.
- o Interferes with the Participant's right to perform the terms and conditions of the Cooperative Agreement.

All technical advice shall be issued in writing by the DOE COTR.

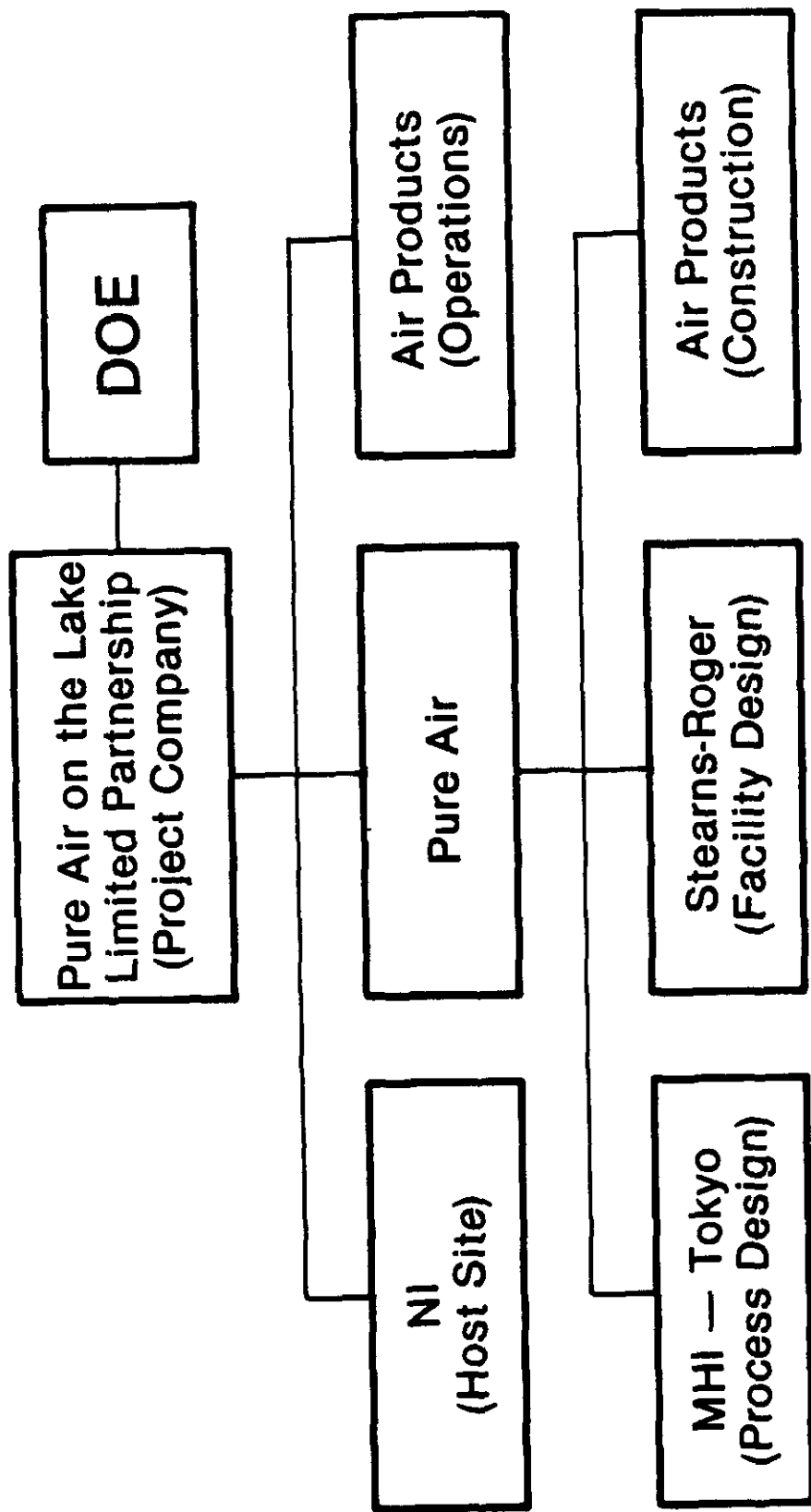
### Participant

The Participant will be responsible for all aspects of project performance under the Cooperative Agreement as set forth in the Statement of Work. Assuming that DOE approves an assignment request from Pure Air, the Participant for this Cooperative Agreement will be the Project Company, Pure Air on the Lake. The Participant will interrelate between the government and all other project team members as shown in Figure 4, Project Structure.

The Participant's Project Manager is the authorized representative for the technical and administrative performance of all work to be performed under the Cooperative Agreement. He/she will be the single authorized point of contact for all matters between the Participant and DOE. The Project Manager will report to the Project Company's ICCT Program Manager. The Program Manager will provide the link to the executives of Air Products, MHIA, NI, and EPRI, and will have final responsibility to the executive management of Pure Air on the Lake for execution of the project.

Pure Air's responsibilities, through a turnkey contract with the Project Company, include the design, procurement, fabrication and installation of the demonstration equipment. Contracts will be let by Pure Air to MHI for the process design, to the Stearns-Roger Division of United Engineers and Constructors for the facility design, and to Air Products for construction of the AFGD plant.

In addition, Air Products, through a contract with the Project Company, will be handling the start-up and on-going operation of the facility during the demonstration period, using the Air Products Operation Manager who will report



**FIGURE 4. AFGD DEMONSTRATION PROJECT ORGANIZATION.**

to the Project Company's Program Manager. Pure Air and NI will provide all services required for the test program, environmental permitting, data analysis and final report preparation.

NI will provide the host site, help produce the data required to obtain necessary permits, modify the Bailly Station to accept the AFGD facility, coordinate the activities of the erection subcontractor, operate and maintain the equipment in their scope of work, provide the test coal, and provide other utilities required for the demonstration project. NI will also enter into an agreement with a wallboard manufacturer for the disposition of the gypsum by-product.

EPRI will work with Pure Air to ensure that information generated during this project is disseminated to the utility industry.

### 5.3 Summary of Project Implementation and Control Procedures

All work to be performed under the Cooperative Agreement is divided into the following phases:

- Phase I: Design and Permitting (35 months)
- Phase II: Construction and Start-up (35 months)
- Phase III: Operation and Disposition (36 months)

Phase I and II will run concurrently. There is a three month overlap between Phases II and III. The project period of performance is 68 months.

Budget periods will be established. Consistent with Public Law No. 100-202, as amended by Public Law No. 100-446, DOE will obligate sufficient funds to cover its share of the cost for each budget period. Throughout the course of this project, reports dealing with the technical, management, cost, and environmental aspects of the project will be prepared by Pure Air and will be provided to DOE.

### 5.4 Key Agreements Impacting Data Rights, Patent Waivers and Information Reporting

Pure Air's incentive to develop this process is to realize retrofit business from, and produce new designs for, the utility and power boiler industry with respect to SO<sub>2</sub> abatement technology. The key agreements with respect to patents and data are:



- o A patent waiver request has been received. The allocation of rights between the Participant and its major subcontractors is not known at this time. However, Pure Air has decided to enter into a Cooperative Agreement with DOE, irrespective of the final patent waiver determination.
- o Standard data provisions are included, giving the Government the right to have delivered, and use, with unlimited rights, all technical data first produced in the performance of the Agreement.
- o License rights in background patents and background data of the Participant and MHIA and all of their subcontractors are included to assure commercialization of the technology in the U.S.

The Participant will make such data, as is applicable and non-proprietary, available to the DOE, Environmental Protection Agency, other interested agencies, and the public.

#### 5.5 Procedures for Commercialization of the Technology

The market for low-cost retrofit SO<sub>2</sub> control technology would be enhanced should regulatory changes occur which would require reductions in SO<sub>2</sub> emissions from non-NSPS utility stations. Currently, about 20 million tons per year of SO<sub>2</sub> are emitted from electric generating stations in the eastern United States, representing about 175,000 MWe or nearly 60% of the nation's coal-fired generating capacity. Any new requirements for SO<sub>2</sub> emission reductions could affect a proportionate share of this capacity, thus stimulating market demand for SO<sub>2</sub> control technology. The purpose of the project is to demonstrate the commercial readiness of the technology for utility application, and to allow clear definition of those site-specific situations in which this technology will be the lowest cost compliance option.

For the proposed technology, there are no unusual fabrication requirements that would preclude the use of existing manufacturing facilities. The nature of the individual components makes the Pure Air process technology compatible with existing power plant and environmental equipment manufacturing methods.

## 6.0 PROJECT COST AND EVENT SCHEDULING

### 6.1 Project Baseline Costs

The total estimated cost for this project is \$150,497,000. The Participants' cash contribution and the Government's share in the cost of this project are as follows:

	Dollar Share (\$)	Percent Share (%)
<u>PRE-AWARD</u>		
Government	1,449,000	42.2
Participant	1,984,000	57.8
<u>PHASE I</u>		
Government	6,409,000	50.0
Participant	6,409,000	50.0
<u>PHASE II</u>		
Government	46,571,000	50.0
Participant	46,571,000	50.0
<u>PHASE III</u>		
Government	9,005,000	21.9
Participant	32,099,000	78.1
<u>TOTAL</u>		
Government	63,434,000	42.2
Participant	87,063,000	57.8

Cash contributions will be made by the co-funders as follows:

DOE	\$ 63,434,000
Pure Air:	\$ 68,815,000
NI:	\$ 18,248,000
TOTAL:	\$150,497,000

At the beginning of each budget period, DOE intends to obligate sufficient funds to pay its share of the expenses for that budget period.

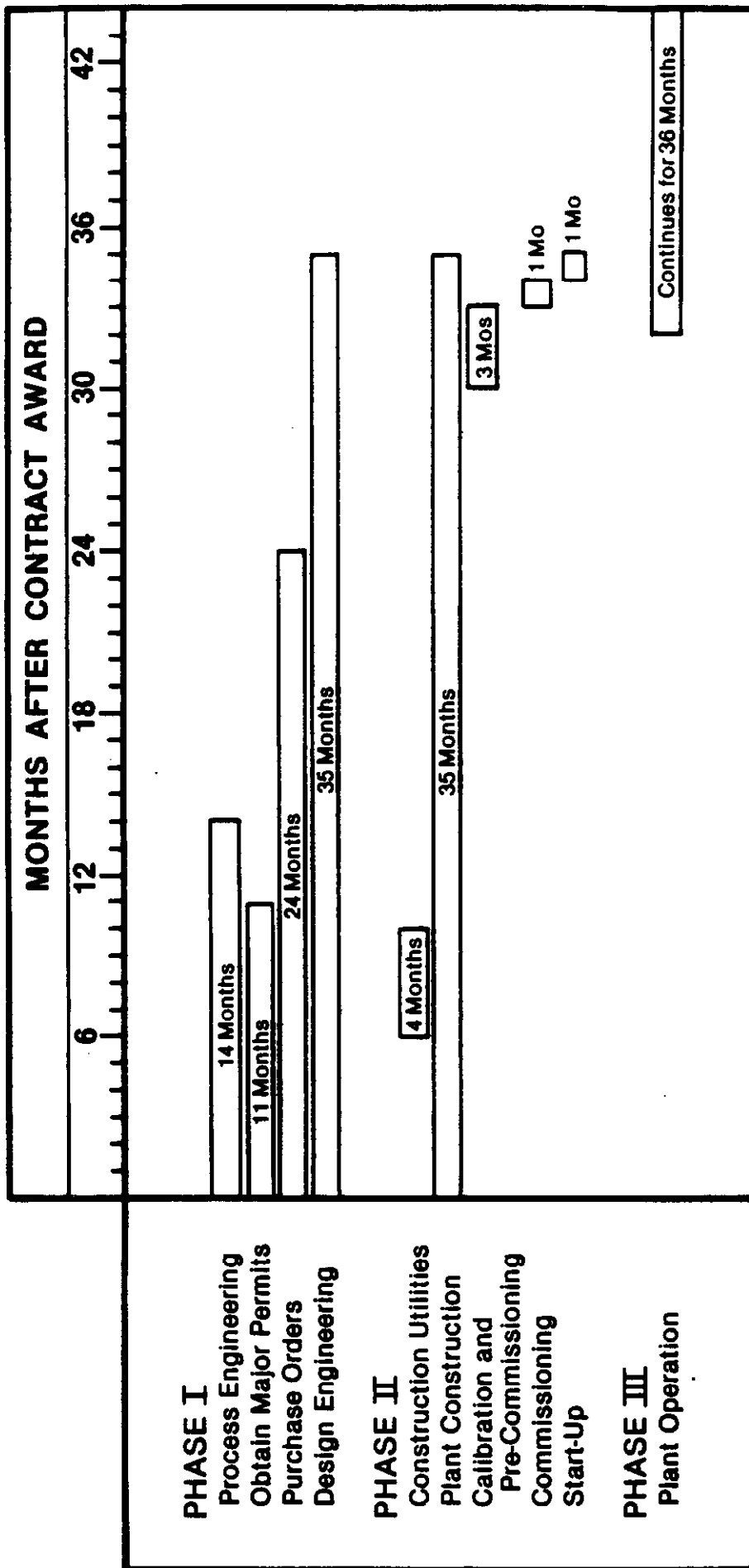
## 6.2 Milestone Schedule

The overall project will be completed in 68 months after award of the Cooperative Agreement as shown in Figure 5.

Phase I which involves design and permitting will start immediately after award of the Cooperative Agreement and last for 35 months. Process engineering will require 14 months and design engineering will be conducted throughout the entire Phase I period. The major permits will be obtained during the first 11 months of Phase I. Phase II, construction and start-up will start and end concurrently with Phase I. Various construction activities will take place throughout the 35 months. Calibration and pre-commissioning activities will start 30 months after the Cooperative Agreement is awarded and will last for three months. Commissioning, which takes one month, will immediately follow calibration and pre-commissioning. The one month start-up period immediately follows commissioning and concludes Phase II. Phase III, plant operation is scheduled to start 32 months after award of the Cooperative Agreement and will continue for three years. This phase will include preparation and dissemination of the final report.

## 6.3 Repayment Plan

Based on DOE's recoupment policy as stated in Section 6.4 of the PON, DOE is to recover an amount up to the Government's contribution to the project. The Participant has agreed to repay the Government in accordance with the Recoupment/Repayment Plan to be included in the final negotiated Cooperative Agreement.



**FIGURE 5. OVERALL SCHEDULE FOR AFGD DEMONSTRATION PROJECT.**